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RESEARCH ARTICLE

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ABSTRACT
The aim of this study was to: (1) verify differences between swimmers of the same competitive level in variables related to the start and finish (50 m and 100 m freestyle); (2) verify if starting and finish variables are responsible for faster race time, and which starting variables are responsible for the start performance in such events. For the 50 m and 100 m freestyle race at the junior European Championships 2019, 86 and 88 male swimmers were analysed, respectively. A set of starting and finishing variables were used for analysis. Both races (50 m: $p < 0.001$; 100 m: $p < 0.001$) presented a significant level effect for the final race time. The same trend was observed for the start and finish performances. For both races, hierarchical linear modelling retained the 15 m mark time and finish speed as predictors. The 50 m start retained the reaction time and underwater speed, and the 100 m start retained the reaction time and the water break distance. This indicates the underwater phase of the start is of substantial importance to improve the 15 m mark time. Coaches and swimmers are advised to enhance the start underwater phase, and finish segments to improve the swimmers' performance.

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Analysis; biomechanics; competition; performance; prediction

1. Introduction

Swimming events can be split-up into start, clean swim, turn(s), and finish (Hay & Guimarães, 1983). In sprint races, such as the 50 m and 100 m freestyle, final race times can differ by as little as hundredths of a second. Small improvements in any segment of the race (i.e. start, clean swim, turn(s), or finish) can make the difference between winning or losing a race. Swimming research is strongly focused on stroke analysis during clean swimming and how to improve it (Morais et al., 2020; Simbaña et al., 2018). The start and finish, especially in sprint events, are also a point of interest for researchers, coaches, and athletes (Born et al., 2021; García-Hermoso et al., 2017). Indeed, small improvements in any of these phases can be decisive to win a race or a medal (Fischer et al., 2017).

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The Fédération Internationale de Natation (FINA) rules allow swimmers to be completely submerged until the 15 m mark and start the swim stroke from that mark onwards (i.e. swimmer's head must have broken the surface by the 15 m mark). The start can be broken down into several spatial-temporal moments, such as the block time, flight time, entry time/distance, underwater time, and surface time (Peterson-Silveira et al., 2018). For instance, it was shown that for sprint swimmers the entry distance was positively and highly related to the force produced during the block time (Calderbank et al., 2020). Moreover, the 15 m mark time was strongly and negatively correlated to a set of variables related to the block time (i.e. higher values of force during the block time promoted less time to reach the 15 m mark) (García-Ramos et al., 2015).

After the block time and water entry, swimmers can adopt two main strategies during the underwater phase: (1) break the water sooner and thus begin the swim stroke sooner, or; (2) break the water later, and hence start the swim stroke later (García-Ramos et al., 2015). However, there is scarce information about which strategy the fastest swimmers choose to optimise the start and consequently the final race time. Overall, it has been shown that the underwater phase can play a key-role on the overall start performance (Tor et al., 2015a). That said, nowadays there is still the need to gather deeper insights about how such spatial-temporal variables can contribute to the start performance (i.e. 15 m start time) in a real competition context (Gonjo & Olstad, 2021; Veiga et al., 2016). Nonetheless, previous studies noted that the start time presents a significant and positive correlation to the final race time in sprint races (Arellano et al., 1994; Mason & Cossor, 2000).

The finish is the last segment of the race, i.e. the last 5 m (Olstad et al., 2020). Few studies analysed its effect on the final race time, especially in sprint events (e.g. Marinho et al., 2020; Olstad et al., 2020). One can consider that the finish is the ability to keep or even increase the swimming speed in the last 5 m of the race, which can be especially determinant in sprint events (Suito et al., 2015). Racing analysis is becoming an even more essential tool to help coaches and athletes enhancing the latter performance (O'Donoghue, 2006).). As aforementioned, literature provides substantial insights on how the fastest swimmers present better clean swimming (i.e. stroke mechanics) in sprinting events (e.g. Arellano et al., 1994; Seifert et al., 2007). Conversely, there is no solid knowledge on what differs the fastest from the slowest swimmers as far as start and finish performances are concerned in short sprints. This information would be extremely helpful for coaches and athletes, providing a better understanding on how they should plan the race strategy.

Therefore, the aim of this study was to: (1) verify if there are differences between swimmers of the same competitive level in the variables related to the start and finish in the 50 m and 100 m freestyle in long-course metre, and; (2) understand which variables are responsible for faster race time and start performances in such events. It was hypothesised that: (1) in both events (i.e. 50 m and 100 m freestyle) faster swimmers reach the 15 m mark time sooner, and they are also faster in the last 5 m (i.e. finish); (2) the 15 m mark time and finish speed (or time) in the last 5 m would be positively related to the fastest race time performances in both events, and the block time would determine the fastest start performance in both events.

2. Methods

2.1. Participants

At the 2019 long course metre LEN European Junior Championships, held in Kazan (Russia), 95 and 106 male swimmers participated in the 50 m freestyle and 100 m freestyle events, respectively. The 50 m performance reached on average 92.04 ± 2.90% and 88.48 ± 2.79% of the 50 m Freestyle junior world record and absolute world record, respectively. The 100 m performance reached on average 92.43 ± 2.56% and 91.13 ± 2.53% of the 100 m Freestyle junior world record and absolute world record, respectively. The University committee approved the study, and the organisation event allowed the use of the footage.

2.2. Data collection

The official race times, reaction times and split times (i.e. 50 m lap) were retrieved from the official competition website (http://ejc2019.microplustiming.com/indexEJC2019_web.php). All video clips were provided by the organisation in high-definition video ($f = 50$ Hz), and at a sampling frequency of 50 Hz. The setup system delivered real-time multi-angle recordings (10 pan-tilt-zoom cameras, AXIS v5915, Lund, Sweden). In every race, each swimmer was recorded by one camera (i.e. one camera per lane) allowing to analyse the start and finish individually. This ensured the calibration of the distances based on the pool's marks (i.e. 5 m, 15 m) for the start analysis. The start flashing lights were synchronised with the official timer and were visible by all cameras. The start flashing light was used as reference to set the time-stamp on the race analysis software (Morais et al., 2019). From all video clips (i.e. one per lane), nine corresponding to the 50 m race and 18 corresponding to the 100 m race were excluded from the analysis since it was not possible to analyse the entire race (from start to finish). Thus, the 50 m performance of the 86 analysed swimmers reached on average 91.93 ± 3.02% and 88.38 ± 2.90% of the 50 m Freestyle junior world record and absolute world record, respectively. The 100 m performance of the 88 analysed swimmers reached on average 92.38 ± 2.70% and 91.08 ± 2.66% of the 100 m Freestyle junior world record and absolute world record, respectively.

2.3. Start and finish

The start variables selected for analysis were: (1) reaction time (also known as block time, the time lag between the starting signal and the instant the swimmer's feet leave the block); (2) flight time (the time lag between the instant the toes leave the block and the hands get in the water); (3) entry time (the time lag between the starting signal and the instant the hands get in the water); (4) entry distance (the distance between the starting head-wall and where the hands get in the water); (5) underwater time (the time lag between the instant the hands get in the water and the head breaks out the water surface); (6) underwater distance (the distance between where the hands get in the water and the head breaks out the water surface); (7) underwater speed (between the entry time and water break time); (8) water break time (the time lag between the starting signal and the moment the head breaks out the water surface); (9) water break distance (the distance between the starting head-wall and the head water break); (10) 15 m mark time (the time lag between the starting signal and the swimmer's head reaches the 15 m mark, which was selected as the main start outcome) (Morais et al., 2020). The finish was considered as the last 5 m (Suito et al., 2015). It was measured as the time spent to travel the last 5 m of the race, and the correspondent speed as: $v = d/t$. The finish time and speed started to be measured when the swimmer's head reached the 45th metre mark and stopped when the swimmer's hand touched the end wall. Therefore, a time and speed correction were made based on the time that the swimmer's head would take to complete the remaining distance (Thompson et al., 2000).

3. Statistical analysis

The Kolmogorov–Smirnov and Levene tests were used to assess the normality and homoscedasticity assumptions, respectively. The mean ± one standard deviation (SD) was computed for all variables.

The dataset of each race (i.e. 50 m and 100 m) was split into two sub-groups: tier #1 and tier #2. For the 50 m race, tier #1 ($N = 43$) included the swimmers with better performances, and tier #2 ($N = 43$) the swimmers with worst performances. For the 100 m race the process was the same (tier #1: $N = 44$; tier #2: $N = 44$). The t-test independent samples ($p \leq 0.05$) were used to compare groups within the same event. Cohen's d was selected as standardised effect size and interpreted as small effect size $0 \leq |d| \leq 0.2$; medium effect size if $0.2 < |d| \leq 0.5$ and; large effect size if $|d| > 0.5$ (Cohen, 1988).

The Pearson's correlation coefficient was used to assess the association between the 50 m and 100 m race times with respective start and finish variables ($p < 0.05$). As rule of thumb, for qualitative and effect size assessments the correlation/relationship was defined as very weak if $r < 0.04$; weak if $0.04 \leq r < 0.16$; moderate if $0.16 \leq r < 0.49$; high if $0.49 \leq r < 0.81$ and; very high of $0.81 \leq r < 1.0$ (Barbosa et al., 2018). Correlation agreements between tiers for each race (i.e. 50 m and 100 m) were computed with Fischer's z-score (Diedenhofen et al., 2015).

Hierarchical linear modelling (HLM) was used to identify the race time (50 m and 100 m) and start time (i.e. 15 m mark time of each race) predictors. For each dependent variable (race time or start time) of each race (50 m and 100 m) two models were tested.

In the first model the race level (i.e. tier #1 versus tier #2) was tested for each dependent variable. The second model related to the race time included all variables as hypothetical predictors. The second model related to the start time (i.e. 15 m mark time) only included the variables related to the start (i.e. all variables except the finish time and finish speed). The final models only included the significant predictors. Maximum likelihood estimation was calculated on HLM7 software (Raudenbush et al., 2011).

4. Results

Figure 1 presents the descriptive data (mean and one SD) for all the selected start and finish variables. It also depicts the variables that presented significant differences between tiers for each race (i.e. 50 m and 100 m).

Table 1 presents the t-test comparison between tiers in each event (i.e. 50 m and 100 m freestyle). In the 50 m freestyle, besides the race time, the 15 m mark time (mean difference = 0.332 s, $t = 7.73$, $p < 0.001$, $d = 1.65$) presented a significant difference

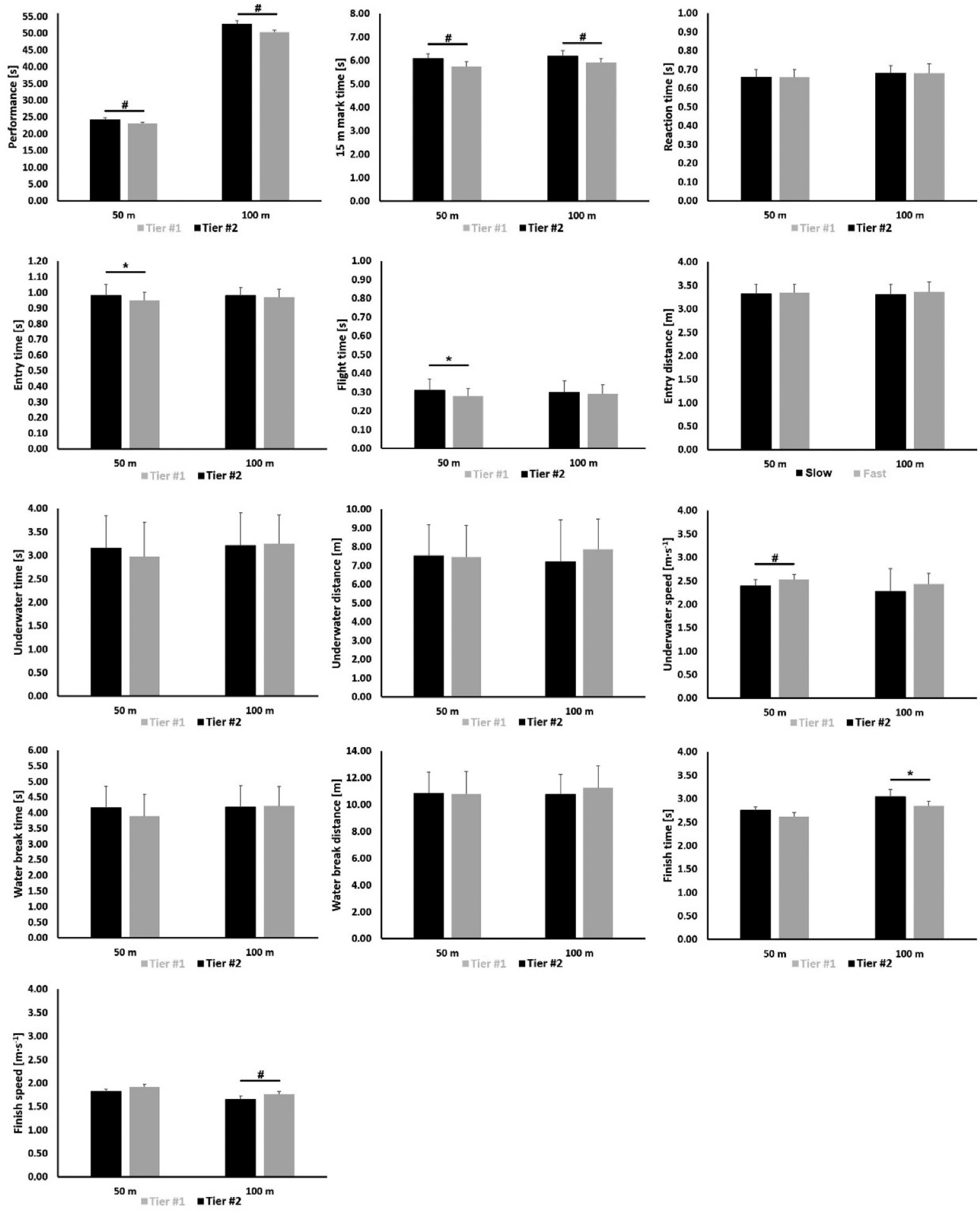

Figure 1. Descriptive data (mean plus one standard deviation) of each tier for the 50 m and 100 m final race time, start and finish. # – $p < 0.001$; * – $p < 0.05$.

between tiers. Conversely, the percentage of contribution the 15 m mark to the race time had no difference (% to the race time: mean difference = 0.117%, t = 0.86, p = 0.392, d = 0.18). In the 100 m freestyle the same trend was observed (15 m mark time: mean difference = 0.274, t = 6.33, p < 0.001, d = 1.34; % to the race time: mean difference = −0.015%, t = −0.24, p = 0.808, d = 0.03) (Table 1). As far as the finish is concerned, significant differences were observed in the 50 m freestyle (finish time: mean

Table 1. Comparison of swimmers included in tier #1 versus tier #2 in the 50 m and 100 m freestyle events.

	50 m tier #1 versus tier #2				100 m tier #1 versus tier #2			
	Mean difference (95 CI)	*t*	*p*	*d*	Mean difference (95 CI)	*t*	*p*	*d*
Race time [s]	1.145 (0.950 to 1.341)	11.63	<0.001	2.39	2.286 (1.940 to 2.631)	13.13	<0.001	2.55
Start								
% to the race time [%]	0.117 (−0.153 to 0.387)	0.86	0.392	0.18	−0.015 (−0.139 to 0.109)	−0.24	0.808	0.03
15 m mark time [s]	0.332 (0.246 to 0.417)	7.73	<0.001	1.65	0.274 (0.188 to 0.359)	6.33	<0.001	1.34
Reaction time [s]	0.008 (−0.008 to 0.024)	0.98	0.329	0.25	0.002 (−0.015 to 0.019)	0.26	0.798	0.00
Entry time [s]	0.029 (0.004 to 0.054)	2.29	0.025	0.49	0.007 (−0.014 to 0.028)	0.70	0.489	0.22
Flight time [s]	0.024 (0.003 to 0.046)	2.23	0.028	0.39	0.006 (−0.017 to 0.029)	0.53	0.599	0.18
Entry distance [m]	−0.020 (−0.107 to 0.067)	−0.46	0.650	0.10	−0.071 (−0.164 to 0.022)	−1.51	0.134	0.33
Underwater time [s]	0.187 (−0.121 to 0.495)	1.21	0.232	0.25	−0.043 (−0.324 to 0.237)	−0.31	0.760	0.06
Underwater distance [m]	0.068 (−0.651 to 0.786)	0.19	0.851	0.04	−0.685 (−1.508 to 0.137)	−1.66	0.101	0.35
Underwater speed [$m \cdot s^{-1}$]	−0.137 (−0.192 to −0.082)	−4.98	<0.001	1.11	−0.158 (−0.320 to 0.004)	−1.94	0.056	0.42
water breakout time [s]	0.216 (−0.084 to 0.516)	1.43	0.157	0.30	−0.036 (−0.312 to 0.240)	−0.26	0.797	0.06
water breakout distance [m]	0.048 (−0.651 to 0.747)	0.14	0.892	0.03	−0.506 (−1.179 to 0.167)	−1.50	0.139	0.32
Finish								
% to the race time [%]	−0.039 (−0.155 to 0.078)	−0.66	0.512	0.15	0.100 (0.012 to 0.189)	2.26	0.027	0.48
Finish time [s]	0.130 (0.094 to 0.165)	7.33	<0.001	1.63	0.188 (0.133 to 0.243)	6.80	<0.001	1.42
Finish speed [$m \cdot s^{-1}$]	−0.090 (−0.114 to −0.066)	−7.43	<0.001	1.63	−0.107 (−0.138 to −0.075)	−6.80	<0.001	1.56

difference = 0.130, t = 7.33, $p < 0.001$, d = 1.63; finish speed: mean difference = −0.090, t = −7.43, $p < 0.001$, d = 1.63), and 100 m freestyle (finish time: mean difference = 0.188, t = 6.80, $p < 0.001$, d = 1.42; finish speed: mean difference = −0.107, t = −6.80, $p < 0.001$, d = 1.56) (Table 1). However, the percentage of contribution to the race time was only significantly different in the 100 m event with a large effect size (% total race time: mean difference = 0.100, t = 2.26, p = 0.027, d = 0.48) (Table 1).

Table 2 consolidates the Pearson's correlation coefficient between the race time for each event (i.e. 50 m and 100 m freestyle) and the start and finish variables for each tier. It also presents the Fischer-z correlation agreement between tier #1 versus tier #2 for each variable. The 50 m and 100 m race time, for both tiers, presented a significant correlation to the correspondent 15 m mark (50 m tier #1: r = 0.624, $p < 0.001$; 50 m tier #2: r = 0.703, $p < 0.001$; z = 0.668, p = 0.504; 100 m tier #1: r = 0.564, $p < 0.001$; 100 m tier #2: r = 0.746, $p < 0.001$; z = 1.472, p = 0.141) (Table 2). For both races (i.e. 50 m and 100 m freestyle), the finish time and speed presented a significant correlation with the correspondent race time in both tiers (Table 2).

Table 3 depicts the significant predictors retained for the 50 m and 100 m race time and start time (i.e. 15 m mark time) of each race (i.e. 50 m and 100 m). In all four models, the level (i.e. tier #1 versus tier #2) presented a significant effect. For the 50 m race time and start, the finish speed (estimate = −4.107, 95 CI: −4.873 to −3.341, $p < 0.001$) and reaction time (estimate = 1.985, 95 CI: 1.195 to 2.775, $p < 0.001$) were the highest contributors, respectively. For the 100 m race, the same trend was verified, where the highest contributor for the race time was the finish speed (estimate = −5.047, 95 CI: −6.858 to −3.236, $p < 0.001$), and the reaction time for the start (estimate = 1.148, 95 CI: 0.101 to 2.195, p = 0.035).

5. Discussion

This study aimed to verify if there are differences between swimmers of the same competitive level in the variables related to the start and finish of the 50 m and 100 m freestyle in long-course metre. It also intended to understand which starting and finish variables are responsible for faster race time, and which variables are responsible for the start performances. Main findings pointed out that, in both 50 m and 100 m freestyle race, the 15 m mark time and the finish time/speed were the responsible variables for the difference between tiers. For both races, the reaction time presented a significant effect in the start.

5.1. Prediction of the race time (50 m and 100 m freestyle) and its relationship with the correspondent start main outcome (15 m mark time) and finish

Mean data comparison showed that for both events (i.e. 50 m and 100 m freestyle) a significant and large difference was observed in the final race time discriminating tiers. The same trend was verified for the start main outcome (i.e. swimmers in tier #1 were also significantly faster reaching the 15 m mark time). Studies aimed to understand how to improve the start performance (Beretić et al., 2013; Takeda et al., 2017), however not much information can be found on the relationship between the start main outcome (15 m mark time) and the final race time. This is particularly important in sprinting events

Table 2. Pearson's correlation coefficient between the race time (50 m and 100 m freestyle) and the correspondent start and finish variables for each tier. It also presents the Fischer-z correlation agreement between tier #1 and tier #2 for each variable in both races (i.e. 50 m and 100 m freestyle).

	50 m race time (tier #1)		50 m race time (tier #2)		Fischer-z		100 m race time (tier #1)		100 m race time (tier #2)		Fischer-z	
	r	*p*	*r*	*p*	*z*	*p*	*r*	*p*	*r*	*p*	*z*	*p*
Start												
% to the race time [%]	0.032	0.844	0.116	0.446	0.378	0.706	0.139	0.362	0.180	0.255	0.189	0.850
15 m mark time [s]	0.624	<0.001	0.703	<0.001	0.668	0.504	0.564	<0.001	0.746	<0.001	1.472	0.141
Reaction time [s]	0.000	1.000	−0.033	0.823	−0.156	0.876	0.054	0.724	0.070	0.621	0.073	0.942
Entry time [s]	0.015	0.924	0.246	0.104	1.114	0.265	0.013	0.933	0.156	0.318	0.653	0.514
Flight time [s]	−0.024	0.880	0.291	0.052	1.527	0.127	−0.036	0.814	0.091	0.563	0.576	0.565
Entry distance [m]	−0.065	0.687	−0.107	0.484	−0.199	0.842	−0.205	0.176	−0.031	0.844	0.801	0.423
Underwater time [s]	0.070	0.663	0.022	0.888	−0.227	0.821	−0.072	0.637	0.007	0.963	0.358	0.720
Underwater distance [m]	−0.014	0.932	−0.096	0.529	−0.388	0.698	−0.126	0.408	−0.093	0.553	0.151	0.880
Underwater speed [$m \cdot s^{-1}$]	−0.400	0.010	−0.455	0.002	−0.318	0.751	−0.117	0.445	−0.146	0.352	−0.134	0.894
water breakout time [s]	0.074	0.646	0.045	0.768	−0.137	0.891	−0.072	0.636	0.020	0.900	0.417	0.677
water breakout distance [m]	−0.022	0.893	−0.115	0.453	−0.441	0.659	−0.150	0.325	−0.155	0.328	−0.023	0.982
Finish												
% to the race time [%]	−0.110	0.483	0.005	0.976	−0.516	0.606	0.165	0.285	0.153	0.321	0.056	0.956
Finish time [s]	0.536	<0.001	0.703	<0.001	−1.228	0.219	0.519	<0.001	0.576	<0.001	−0.369	0.712
Finish speed [$m \cdot s^{-1}$]	−0.537	<0.001	−0.695	<0.001	1.152	0.249	−0.525	<0.001	−0.549	<0.001	0.153	0.879

Table 3. Fixed effects of the final models computed with standard errors (SE) and 95% confidence intervals (95 CI). For each race (50 m and 100 m freestyle), two prediction models were computed: (1) race time (total race time), and; (2) 15 m mark time (start main outcome).

Parameter Fixed Effect	Estimate (SE)	95 CI	p value
50 m race time			
Intercept	21.871 (1.137)	(19.642 to 24.100)	<0.001
Level	−0.333 (0.067)	(−0.464 to −0.202)	<0.001
Water break time	0.139 (0.038)	(0.065 to 0.213)	<0.001
15 m mark time	1.503 (0.126)	(1.256 to 1.750)	<0.001
Finish speed	−4.107 (0.391)	(−4.873 to −3.341)	<0.001
50 m start (i.e. 15 m mark time)			
Intercept	7.270 (0.369)	(6.547 to 7.993)	<0.001
Level	−0.180 (0.034)	(−0.247 to −0.113)	<0.001
Reaction time	1.985 (0.403)	(1.195 to 2.775)	<0.001
Underwater speed	−1.045 (0.157)	−1.353 to −0.737)	<0.001
100 m race time			
Intercept	43.732 (2.898)	(38.052 to 49.412)	<0.001
Level	−1.087 (0.178)	(−1.436 to −0.738)	<0.001
15 m mark time	2.718 (0.368)	(1.997 to 3.439)	<0.001
Finish speed	−5.047 (0.924)	(−6.858 to −3.236)	<0.001
100 m start (i.e. 15 m mark time)			
Intercept	5.794 (0.411)	(4.988 to 6.600)	<0.001
Level	−0.253 (0.038)	(−0.327 to −0.179)	<0.001
Reaction time	1.148 (0.534)	(0.101 to 2.195)	0.035
Water break distance	−0.036 (0.011)	(−0.058 to −0.014)	0.002

such as the 100 m freestyle. The start may account 11.96 ± 0.26% to the final race time (Morais et al., 2019). No information was found about the contribution of the start to the 50 m race in elite swimming. Our data revealed that the start contributed with 25.02 ± 0.63% and 11.59 ± 1.28%, to the 50 m and 100 m races, respectively. A study by McGowan et al. (2017) showed that improvements in the 15 m mark time promoted an enhancement in the 100 m race time. Thus, one can claim that small gains in the start can lead to meaningful improvements in the final race time.

The finish performance also presented a significant and large difference between tiers. For both races, swimmers in tier #1 showed a higher and significant swim speed (and consequently less time to cover the distance) in the last 5 m of the race. The finish contributed with 10.19 ± 0.24% and 5.14 ± 0.20% to the 50 m and 100 m races, respectively. Once more, small improvements in the finish might have an impact on the final race time. A scarce number of studies assessed the influence of the finish on freestyle sprint races (e.g. Mason & Cossor, 2000; Suito et al., 2015). A moderate-high correlation was found between the final race time and the start main outcome for the 100 m freestyle (Mason & Cossor, 2000; Suito et al., 2015), and a high correlation for the 50 m freestyle (Mason & Cossor, 2000). Our data indicate that the mean difference between tiers was higher in the 100 m race than in the 50 m. In addition, such differences were of substantial magnitude in comparison to the ones verified in the 50 m. Overall, it can be suggested that a strong finish in both events promotes a faster final race time, with greater improvements in the 100 m race.

Hierarchical linear modelling was used to understand if the final race time could be determined by the start and finish variables. This modelling approach was also used to confirm a level effect (i.e. competitive level: difference between tiers), which was verified in both races. In both events, the start main outcome (i.e. 15 m mark time) and the finish speed predicted the final race time. Researchers and coaches focus highly on the swimmer's stroke mechanics to increase swim speed (Anderson et al., 2006; Simbaña-Escobar et al., 2020), however, based on the evidence reported here, it should be argued that in sprint races the start and finish segments play key-roles on the final race time.

5.2. Prediction of the start main outcome (15 m mark time) in each race (50 m and 100 m freestyle) and its relationship with other starting variables

As aforementioned, the start main outcome (i.e. 15 m mark time) can be determinant for the final race time in sprint races. Several studies aimed to understand how the start can be improved (Burkhardt et al., 2020; Peterson-Silveira et al., 2018; Tor et al., 2015a). In the 50 m freestyle, the entry time, flight time and underwater speed were the variables presenting significant and medium-large level effects (i.e. tier #1 versus tier #2 significant differences). In the 100 m freestyle, there were not significant differences in any variable. Nonetheless, the underwater speed was very close to a significant level effect (medium effect size). It was noted that the 15 m mark time was significantly correlated (i.e. higher values led to less time covering the distance) to the average horizontal force, horizontal take-off velocity and average horizontal acceleration (García-Ramos et al., 2015; Thing et al., 2021). Furthermore, it was also significantly correlated to variables related to lower-limbs explosiveness (squat and countermovement height) (Keiner et al., 2019; West et al., 2011). Thus, one can suggest that increasing lower-limbs strength and power can promote meaningful effects on the swimmers' start.

Our data showed that the underwater speed (related to the underwater phase) was the variable that presented the most considerable effect in both race distances, but significant only in the 50 m freestyle. Studies indicated that in 100 m events, swimmers reaching faster underwater speeds had a meaningful advantage on swimming start, and consequently on the final race times (Olstad et al., 2020; Sánchez et al., 2021). Other studies focused on understanding the undulatory swimming (Wadrzyk et al., 2021) or the transition from the underwater phase to surface swim (Stosic et al., 2021; Trinidad et al., 2020). Overall, for the front crawl stroke (i.e. freestyle event) it was noted that the body depth and inclination were key factors on the transition between underwater and surface (Stosic et al., 2021). Conversely, no information was found on this matter for the 50 m events. That said, swimmers are advised to keep in the underwater phase as the underwater speed is faster than clean swim. Thus, knowing the best moment to shift from the underwater to surface swim stroke is of paramount importance for any swimmers who are willing to enhance the start performance (Trinidad et al., 2020).

The prediction modelling of the start main outcome (i.e. 15 m mark time) by HLM retained the level (i.e. competitive level) as significant predictor. In both events the reaction time was also retained. Past literature reported that the fastest sprint swimmers had quicker reaction times in comparison to slower counterparts (Garcia-Hermoso et al., 2013). The 50 m modelling also retained the underwater speed, and the 100 m retained the water break distance. In the case of the 50 m race, a faster underwater speed was related to less time to reach the 15 m mark. It was verified that explosiveness by the lower limbs was determinant to achieve a water entry farther from the head wall and a faster underwater speed (Calderbank et al., 2020). Moreover, swimmers can perform underwater dolphin kicks until reaching the 15 m mark. A study by Ikeda et al. (2021) showed that posture and kick motion presented a higher significant effect on the swimmer's dolphin kick performance than the kick cycle frequency (Ikeda et al., 2021). This indicates that swimmers should put substantial focus on their underwater technique ton increase the start performance (i.e. less time to cover the 15 m mark).

For the 100 m race, an increase in the water break distance was related to less time reaching the 15 m mark. Swimmers racing the 100 m freestyle event are mindful on the need to save some energy at the beginning of the race by enhancing their underwater phase (through the increase in their water break distance). Notwithstanding, the same rational was reported comparing the 100 m and 200 m races (Marinho et al., 2020). As aforementioned, swimmers perform dolphin kicks during the underwater phase (i.e. under surface). This allows them to save energy due to depth. It was showed that travelling deeper than 0.5 m under the surface for as long as possible reduces the effect of drag (which will lead to energy saving) (Tor et al., 2015b). Thus, it can be claimed that swimmers present different strategies depending on the sprint distance to be raced. In the 50 m race, swimmers are willing to go all-out from the beginning of the race, not pacing themselves or taking into consideration any kind of energy saving. In the 100 m race, swimmers should be advised to increase the water break distance which will allow them to save energy for the clean swim phase. Based on this data, coaches should employ different start strategies based on the race distance (i.e. 50 m or 100 m freestyle).

6. Conclusion

A significant level effect (i.e. difference between tiers) was verified for the 50 m and 100 m freestyle races. The 15 m mark time (i.e. start main outcome) and the finish speed were the variables responsible for such difference, where a faster start and finish were related to better performances. The reaction time (block time) and the underwater phase (50 m race: underwater speed; 100 m race: water break distance) were the variables that predicted the start performance. Coaches and swimmers are advised to enhance the start and finish segments to improve the swimmers' performance. They should also dedicate enough time to understand and identify the best moment for water break (i.e. underwater-surface transition).

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